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Hiller

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(54) **OPTICAL PHASE MODULATOR**

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G02B 6/293 (2006.01)
G02F 1/21 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/2935*** (2013.01); *G02B 6/29352* (2013.01); *G02F 2001/212* (2013.01)

(58) **Field of Classification Search**
CPC G02B 6/2935
See application file for complete search history.

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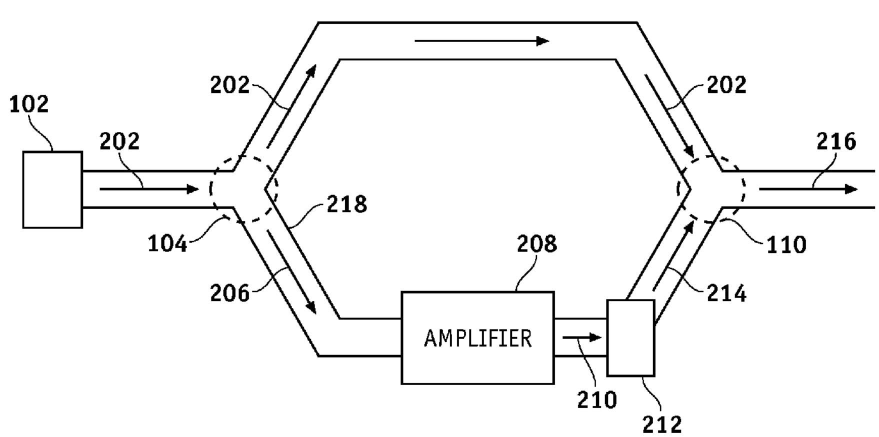
(57) **ABSTRACT**

An optical phase modulator and modulation method is disclosed. An optical splitter diverts a portion of an input light signal into at least one diverted light signal, and at least one optical amplifier amplifies the at least one diverted light signal to provide at least one amplified light signal. At least one static phase shifter statically phase shifts the at least one amplified light signal to provide at least one phase-shifted diverted light signal, and an optical combiner combines the input light signal with the at least one phase-shifted diverted light signal to provide a phase-shifted combined light signal.

20 Claims, 4 Drawing Sheets

200



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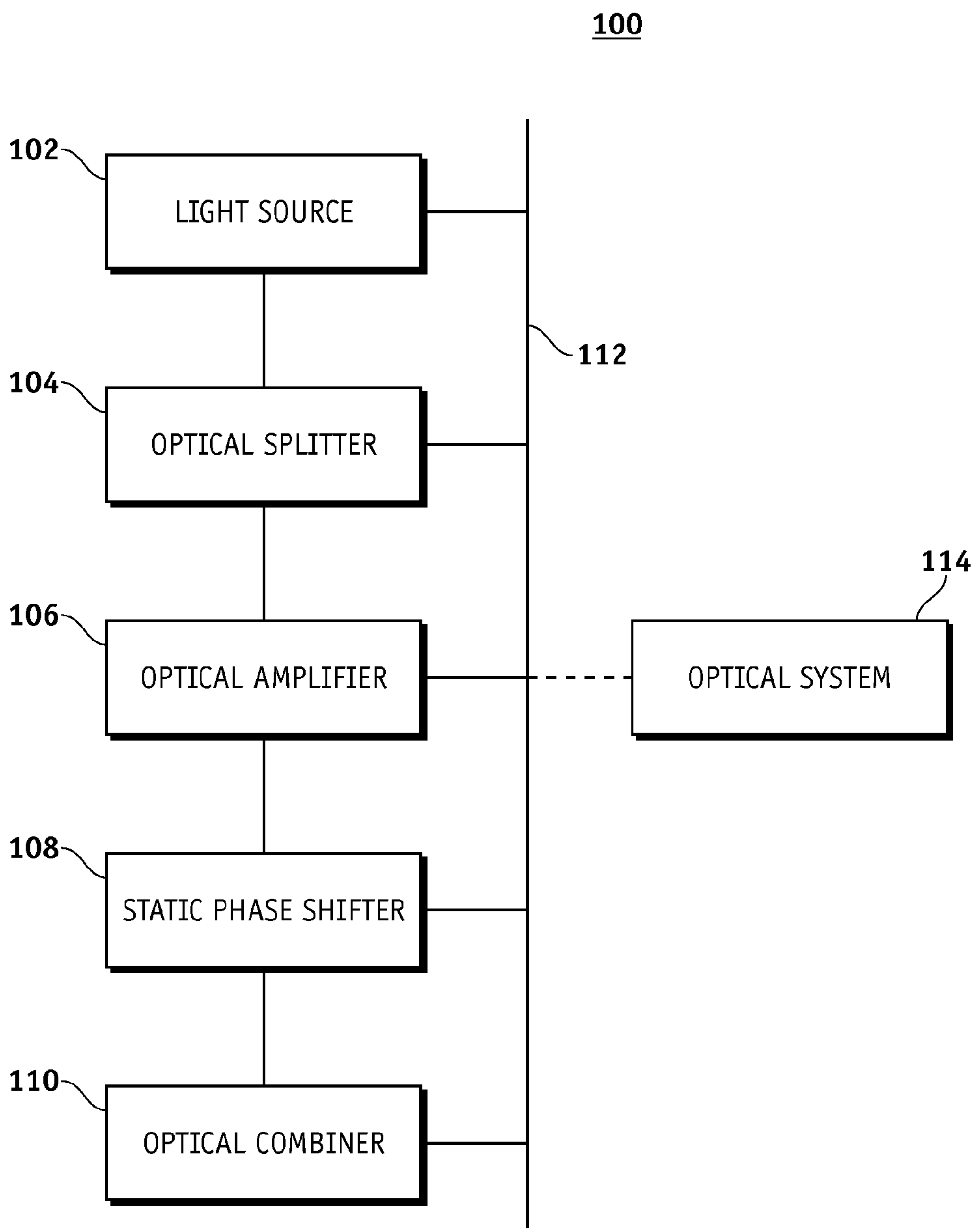
100
102
LIGHT SOURCE
104
OPTICAL SPLITTER
106
OPTICAL AMPLIFIER
108
STATIC PHASE SHIFTER
110
OPTICAL COMBINER
112
114
OPTICAL SYSTEM

FIG. 1

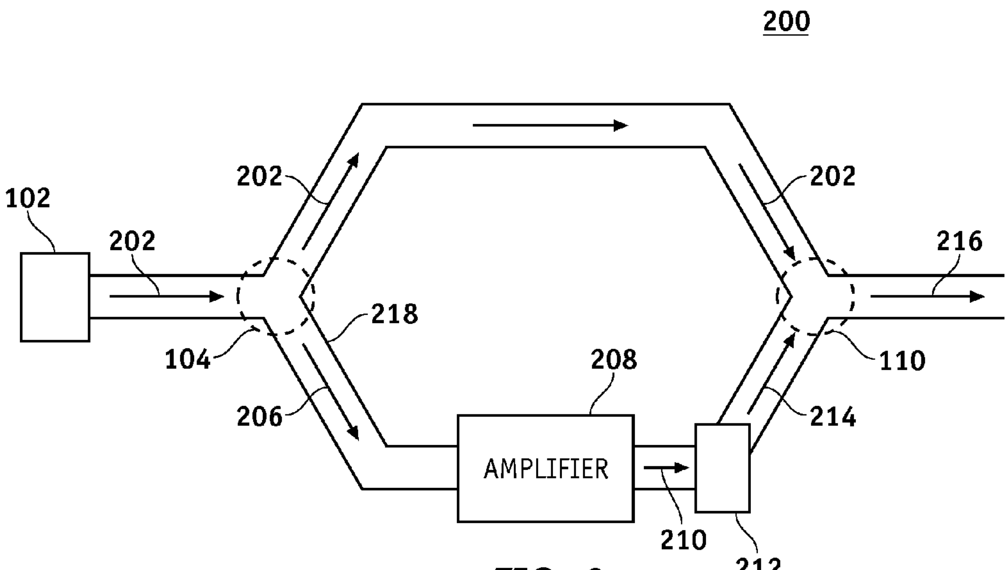
200
102
202
202
202
216
218
104
110
208
206
214
AMPLIFIER
210
212

FIG. 2

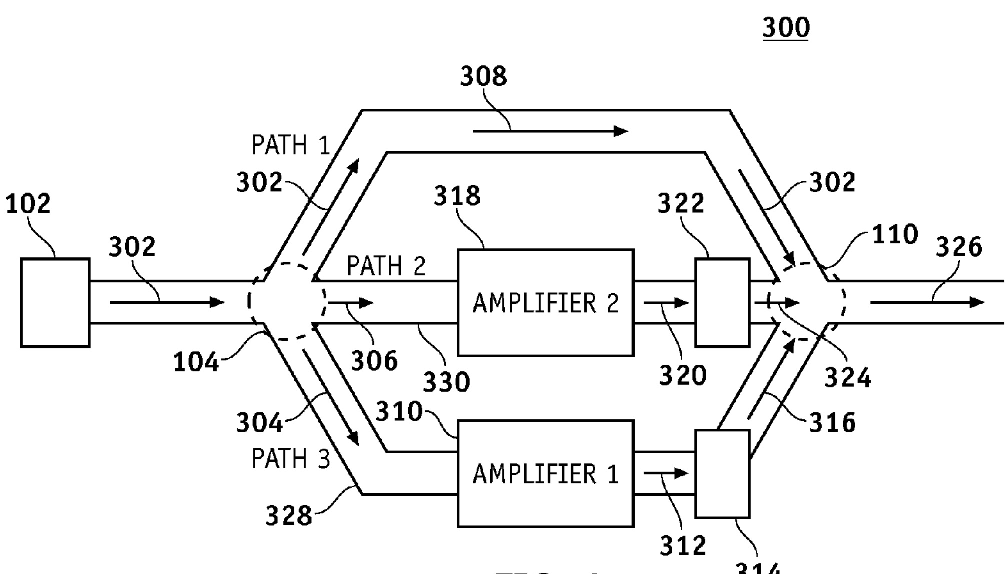
300
308
PATH 1
302
302
102
318
322
110
302
326
PATH 2
AMPLIFIER 2
104
306
330
320
324
304
310
316
PATH 3
AMPLIFIER 1
328
312
314

FIG. 3

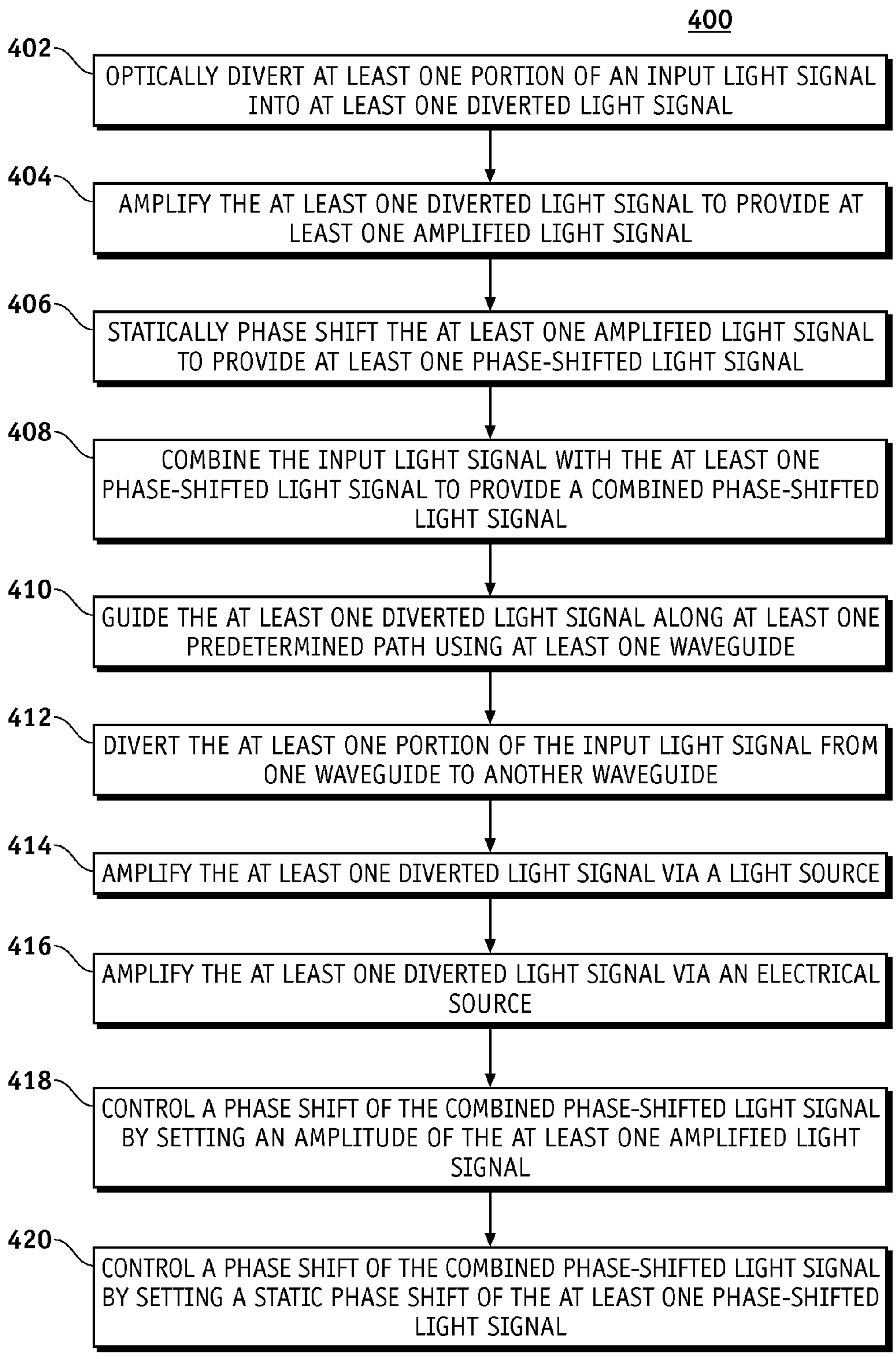
400
402
OPTICALLY DIVERT AT LEAST ONE PORTION OF AN INPUT LIGHT SIGNAL INTO AT LEAST ONE DIVERTED LIGHT SIGNAL
404
AMPLIFY THE AT LEAST ONE DIVERTED LIGHT SIGNAL TO PROVIDE AT LEAST ONE AMPLIFIED LIGHT SIGNAL
406
STATICALLY PHASE SHIFT THE AT LEAST ONE AMPLIFIED LIGHT SIGNAL TO PROVIDE AT LEAST ONE PHASE-SHIFTED LIGHT SIGNAL
408
COMBINE THE INPUT LIGHT SIGNAL WITH THE AT LEAST ONE PHASE-SHIFTED LIGHT SIGNAL TO PROVIDE A COMBINED PHASE-SHIFTED LIGHT SIGNAL
410
GUIDE THE AT LEAST ONE DIVERTED LIGHT SIGNAL ALONG AT LEAST ONE PREDETERMINED PATH USING AT LEAST ONE WAVEGUIDE
412
DIVERT THE AT LEAST ONE PORTION OF THE INPUT LIGHT SIGNAL FROM ONE WAVEGUIDE TO ANOTHER WAVEGUIDE
414
AMPLIFY THE AT LEAST ONE DIVERTED LIGHT SIGNAL VIA A LIGHT SOURCE
416
AMPLIFY THE AT LEAST ONE DIVERTED LIGHT SIGNAL VIA AN ELECTRICAL SOURCE
418
CONTROL A PHASE SHIFT OF THE COMBINED PHASE-SHIFTED LIGHT SIGNAL BY SETTING AN AMPLITUDE OF THE AT LEAST ONE AMPLIFIED LIGHT SIGNAL
420
CONTROL A PHASE SHIFT OF THE COMBINED PHASE-SHIFTED LIGHT SIGNAL BY SETTING A STATIC PHASE SHIFT OF THE AT LEAST ONE PHASE-SHIFTED LIGHT SIGNAL

FIG. 4

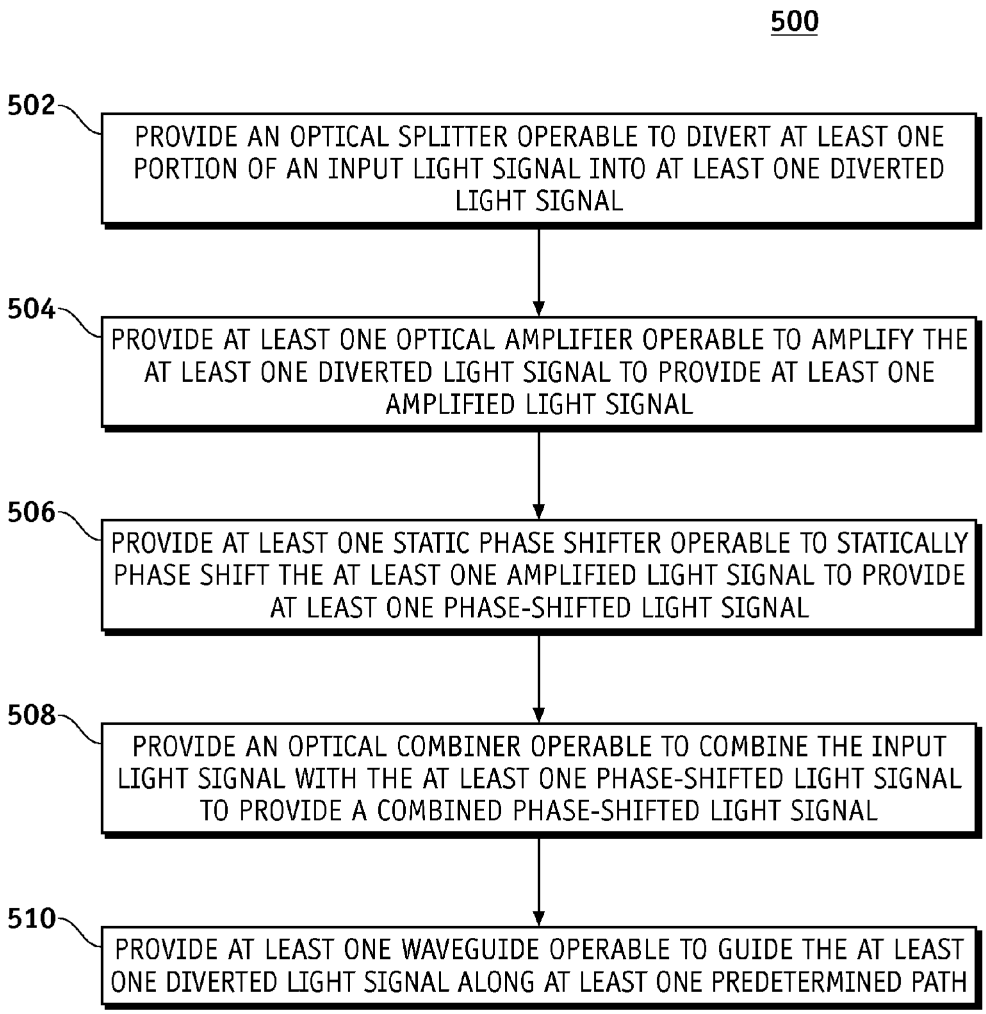
500
502
PROVIDE AN OPTICAL SPLITTER OPERABLE TO DIVERT AT LEAST ONE PORTION OF AN INPUT LIGHT SIGNAL INTO AT LEAST ONE DIVERTED LIGHT SIGNAL
504
PROVIDE AT LEAST ONE OPTICAL AMPLIFIER OPERABLE TO AMPLIFY THE AT LEAST ONE DIVERTED LIGHT SIGNAL TO PROVIDE AT LEAST ONE AMPLIFIED LIGHT SIGNAL
506
PROVIDE AT LEAST ONE STATIC PHASE SHIFTER OPERABLE TO STATICALLY PHASE SHIFT THE AT LEAST ONE AMPLIFIED LIGHT SIGNAL TO PROVIDE AT LEAST ONE PHASE-SHIFTED LIGHT SIGNAL
508
PROVIDE AN OPTICAL COMBINER OPERABLE TO COMBINE THE INPUT LIGHT SIGNAL WITH THE AT LEAST ONE PHASE-SHIFTED LIGHT SIGNAL TO PROVIDE A COMBINED PHASE-SHIFTED LIGHT SIGNAL
510
PROVIDE AT LEAST ONE WAVEGUIDE OPERABLE TO GUIDE THE AT LEAST ONE DIVERTED LIGHT SIGNAL ALONG AT LEAST ONE PREDETERMINED PATH

FIG. 5

OPTICAL PHASE MODULATOR

FIELD

Embodiments of the present disclosure relate generally to electro-optics. More particularly, embodiments of the present disclosure relate to electro-optic devices.

BACKGROUND

Optical phase modulators have numerous applications such as: active mode locking of a laser, stabilization of a laser frequency, wavelength tuning of a single-frequency laser, enabling a core technology for interferometers, generating frequency combs for some metrology applications, or other applications. Dynamically changing a phase of light can be achieved by, for example, dynamically changing a length of a light path (e.g., stretching a waveguide), or by dynamically changing a refractive index of a medium in which light travels. The refractive index of a medium can be changed by, electric field, magnetic field, stress field, temperature, quantum-confined Stark effect, free-carrier plasma dispersion, or other means. However, dynamically changing a length of the light path is a mechanical process, and therefore it is energy inefficient and slow. An ability to dynamically change the refractive index in some materials is limited and may be difficult.

SUMMARY

An optical phase modulator and modulation methods are disclosed. An optical splitter diverts at least one portion of an input light signal into at least one diverted light signal, and at least one optical amplifier amplifies the diverted light signal to provide at least one amplified light signal. At least one static phase shifter statically phase shifts the amplified light signal to provide at least one phase-shifted diverted light signal, and an optical combiner combines the input light signal with the phase-shifted diverted light signal to provide a phase-shifted combined light signal.

In this manner, issues associated with non-optimal processes of current optical phase modulators are solved. These non-optimal processes may comprise, for example but without limitation, an energy inefficient and slow process of dynamically changing the path length of light, a limited ability to dynamically change a refractive index in some materials, or other non-optimal process.

In an embodiment, an optical phase modulator comprises an optical splitter, at least one optical amplifier, at least one static phase shifter, and an optical combiner. The optical splitter is operable to divert at least one portion of an input light signal into at least one diverted light signal. The at least one optical amplifier is operable to amplify the at least one diverted light signal to provide at least one amplified light signal. The static phase shifter is operable to statically phase shift the at least one amplified light signal to provide at least one phase-shifted diverted light signal. The optical combiner is operable to combine the input light signal with the at least one phase-shifted diverted light signal to provide a phase-shifted combined light signal.

In another embodiment, a method for dynamically phase shifting a light signal optically diverts at least one portion of an input light signal into at least one diverted light signal. The method further amplifies the at least one diverted light signal to provide at least one amplified light signal, and statically phase shifts the at least one amplified light signal to provide at least one phase-shifted light signal. The method further combines the input light signal with the at least one phase-shifted light signal to provide a combined phase-shifted light signal.

In a further embodiment, a method for providing an optical phase modulator provides an optical splitter operable to divert at least one portion of an input light signal into at least one diverted light signal. The method further provides at least one optical amplifier operable to amplify the at least one diverted light signal to provide at least one amplified light signal. The method further provides at least one static phase shifter operable to statically phase shift the at least one amplified light signal to provide at least one phase-shifted light signal. The method further provides an optical combiner operable to combine the input light signal with the at least one phase-shifted light signal to provide a combined phase-shifted light signal.

This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF DRAWINGS

A more complete understanding of embodiments of the present disclosure may be derived by referring to the detailed description and claims when considered in conjunction with the following figures, wherein like reference numbers refer to similar elements throughout the figures. The figures are provided to facilitate understanding of the disclosure without limiting the breadth, scope, scale, or applicability of the disclosure. The drawings are not necessarily made to scale.

FIG. **1** is an illustration of an exemplary functional block diagram of a phase modulator according to an embodiment of the disclosure.

FIG. **2** is an illustration of an exemplary optical phase modulation showing a light signal flow according to an embodiment of the disclosure.

FIG. **3** is an illustration of an exemplary optical phase modulation showing a light signal flow according to an embodiment of the disclosure.

FIG. **4** is an illustration of an exemplary flowchart showing a process for dynamically phase shifting a light signal according to an embodiment of the disclosure.

FIG. **5** is an illustration of an exemplary flowchart showing a process for providing a phase modulator according to an embodiment of the disclosure.

DETAILED DESCRIPTION

The following detailed description is exemplary in nature and is not intended to limit the disclosure or the application and uses of the embodiments of the disclosure. Descriptions of specific devices, techniques, and applications are provided only as examples. Modifications to the examples described herein will be readily apparent to those of ordinary skill in the art, and the general principles defined herein may be applied to other examples and applications without departing from the spirit and scope of the disclosure. The present disclosure should be accorded scope consistent with the claims, and not limited to the examples described and shown herein.

Embodiments of the disclosure may be described herein in terms of functional and/or logical block components and various processing steps. It should be appreciated that such block components may be realized by any number of hardware, software, and/or firmware components configured to perform the specified functions. For the sake of brevity, conventional techniques and components related to optical sources, optical properties, phase modulation techniques, and other functional aspects of systems described herein (and the individual operating components of the systems) may not be described in detail herein. In addition, those skilled in the art will appreciate that embodiments of the present disclosure may be practiced in conjunction with a variety of hardware and software, and that the embodiments described herein are merely example embodiments of the disclosure.

Embodiments of the disclosure are described herein in the context of a practical non-limiting application, namely, optical modulation. Embodiments of the disclosure, however, are not limited to such optical modulation applications, and the techniques described herein may also be utilized in other applications. For example but without limitation, embodiments may be applicable to microwaves, radio waves, sound waves, and other signals.

As would be apparent to one of ordinary skill in the art after reading this description, the following are examples and embodiments of the disclosure and are not limited to operating in accordance with these examples. Other embodiments may be utilized and structural changes may be made without departing from the scope of the exemplary embodiments of the present disclosure.

To dynamically phase shift light, most optical phase modulators modify a medium in which light propagates. In contrast, embodiments of the disclosure provide a system and methods for phase modulating a light signal that dynamically phase shifts light by directly modifying the light as explained below.

FIG. **1** is an illustration of an exemplary functional block diagram of an optical phase modulator **100** (system **100**) according to an embodiment of the disclosure. The system **100** dynamically phase shifts light by directly modifying the light. This direct modification of light is accomplished by diverting an input light signal, amplifying the diverted light signal, statically phase shifting the diverted amplified light signal, and then recombining the diverted phase shifted amplified light signal with the input light signal.

The system **100** may comprise a light source **102**, an optical splitter **104**, at least one optical amplifier **106**, at least one static phase shifter **108**, and an optical combiner **110**. A practical system **100** may comprise any number of processor modules, any number of memory modules, and any number of other modules. The illustrated system **100** depicts a simple embodiment for ease of description. These and other elements of the system **100** are interconnected together, allowing communication between the various elements of system **100**. The system **100** may be coupled to an optical system **114** for a variety of applications discussed below.

In one embodiment, these and other elements of the system **100** may be interconnected together via a communication link **112**. Those of skill in the art will understand that the various illustrative blocks, modules, circuits, and processing logic described in connection with the embodiments disclosed herein may be implemented in hardware, computer-readable software, firmware, or any practical combination thereof.

To illustrate clearly this interchangeability and compatibility of hardware, firmware, and software, various illustrative components, blocks, modules, circuits, and steps are described generally in terms of their functionality. Whether such functionality is implemented as hardware, firmware, or software depends upon the particular application and design constraints imposed on the overall system. Those familiar with the concepts described herein may implement such functionality in a suitable manner for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure. System **100** is described below in conjunction with FIG. **2**.

The light source **102** is operable to generate an input light signal **202** (FIG. **2**) for the system **100**. The light source **102** may comprise, for example but without limitation, a laser, or other coherent wave source.

The optical splitter **104** is operable to divert a portion of the input light signal **202** into at least one diverted light signal **206**. At least one waveguide **218** may be used to guide the at least one diverted light signal **206** along at least one predetermined path.

The optical amplifier **106** (**208** in FIG. **2**) is operable to amplify the diverted light signal **206** to provide at least one amplified light signal **210**. The optical amplifier **106** may be further operable to be set to a specified amplification.

The static phase shifter **108** (**212** in FIG. **2**) is operable to statically phase shift the amplified light signal **210** to provide at least one phase-shifted diverted light signal **214**. The static phase shifter **108** may be further operable to be set to a specified static phase shift.

The optical combiner **110** is operable to combine the input light signal **202** with the at least one phase-shifted diverted light signal **214** to provide a phase-shifted combined light signal **216**.

The optical system **114** may be coupled to the system **100** for a variety of applications. For example but without limitation, the system **100** may be used in the optical system **114** for: an optical computation system, a laser, an interferometer, a frequency comb (e.g., for a metrology application), an optical communication system (e.g., for encoding data), or other application. Further, for example but without limitation, the system **100** may be used for a laser in the optical system **114** for: active mode locking of a laser, stabilization of a laser frequency, wavelength tuning of a single-frequency laser, or other laser application. Additionally, for example but without limitation, the system **100** may be used in the optical system **114** for an optical computation system as: a computation block, an amplifier, or other computation element.

FIG. **2** is an illustration of an exemplary optical phase modulator **200** (system **200**) showing a light signal flow according to an embodiment of the disclosure. The system **200** may have functions, material, and structures that are similar to the embodiments shown in FIG. **1**. Therefore, common features, functions, and elements may not be redundantly described here. System **200** is described below in conjunction with FIG. **1**.

The input light signal **202** is generated by the light source **102**. A portion of the input light signal **202** is then diverted by the optical splitter **104** into at least one waveguide to form the diverted light signal **206**. The diverted light signal **206** is amplified by an optical amplifier **208** (**106** in FIG. **1**) into an amplified light signal **210**. The amplified light signal **210** is statically phase shifted by a static phase shifter **212** into the phase-shifted light signal **214**. The phase-shifted light signal **214** and the input light signal **202** are then combined by the optical combiner **110** to provide the combined phase-shifted light signal **216** at an output of the system **200**.

FIG. **3** is an illustration of an exemplary optical phase modulator **300** (system **300**) showing a light signal flow according to an embodiment of the disclosure according to an embodiment of the disclosure. The system **300** may have functions, material, and structures that are similar to the embodiments shown in FIG. **1**. Therefore, common features, functions, and elements may not be redundantly described here. System **300** is described below in conjunction with FIG. **2**.

An input light signal **302** is generated by the light source **102**. A first portion and a second portion of the input light signal **302** are diverted by the optical splitter **104** into two waveguides such as a first waveguide **328** and a second waveguide **330** to form a first diverted light signal **304**, and a second diverted light signal **306** respectively. The first diverted light signal **304** is amplified by a first optical amplifier **310** into a first amplified light signal **312**. The first amplified light signal **312** is statically phase shifted by a static phase shifter **314** into a first phase-shifted light signal **316**. The second diverted light signal **306** is amplified by a second optical amplifier **318** into a second amplified light signal **320**. The second amplified light signal **320** is statically phase shifted by a second static phase shifter **322** into a second phase-shifted light signal **324**.

The first phase-shifted light signal **316**, the second phase-shifted light signal **324**, and the input light signal **302** are combined by the optical combiner **110** to provide a combined phase-shifted light signal **326** at an output of the system **300**.

Diverted light signals may be guided along respective predetermined paths using respective waveguides. For example, in the embodiment shown in FIG. **3**, the first diverted light signal **304**, and the second diverted light signal **306** are split between the first waveguide **328** (along path 3) and the second waveguide **330** (along path 2). Path 2 has a length that is equal to path 1 (or a multiple of 2π). Path 3 has a length that is about +/−2.1 radians different than path 2. By adjusting an amplification of each of the optical amplifiers **318**/**310** on each of the path 2 and the path 3 respectively, a phase of the combined phase-shifted light signal **326** can be tuned to, for example but without limitation, between about 0 and about 1.04 radians, or other suitable phase shift. Efficiency may drop off beyond 1.04 radians. Concurrently, a magnitude of the combined phase-shifted light signal **326** is equal to the input light signal **302**. A substantially maximum total power required for the optical amplifiers **318**/**310** is equal to (an input signal power of the input light signal **302**)/(amplifier efficiency).

The second optical amplifier **318** may only be needed to improve maintaining constant output power over using a single optical amplifier. However, if the second optical amplifier **318** is eliminated, the output power may only decrease, for example but without limitation, between about 0% and about 3%. Since such a loss of power may be acceptable for many applications, the second optical amplifier **318** may be removed to simplify the manufacture and operation of the system **300**.

To achieve dynamic phase shifts greater than 1.04 radians, a user can increase a static phase shift of the static phase shifter **314** on the path 3 or of the static phase shifter **322** on the path 2 to greater than about +/−2.1 radians, however power efficiency may decrease.

In one embodiment, any of the systems **200** through system **300** may be duplicated and combined in series so that a total phase shift of N×1.04 can result, where N is an integer.

FIG. **4** is an illustration of an exemplary flowchart showing a process **400** for dynamically phase shifting a light signal according to an embodiment of the disclosure. The various tasks performed in connection with the process **400** may be performed mechanically, by software, hardware, firmware, a computer-readable medium having computer executable instructions for performing the processes, or any combination thereof.

It should be appreciated that process **400** may include any number of additional or alternative tasks, the tasks shown in FIG. **4** need not be performed in the illustrated order, and the process **400** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein. For illustrative purposes, the following description of process **400** may refer to elements mentioned above in connection with FIGS. **1**-**3**.

In practical embodiments, portions of the process **400** may be performed by different elements of the system **100** through **300** such as: the light source **102**, the optical splitter **104**, the optical amplifier **106**/**208**/**310**/**318**, the static phase shifter **108**/**212**/**314**/**322**, the optical combiner **110**, etc. Process **400** may have functions, material, and structures that are similar to the embodiments shown in FIGS. **1**-**3**. Therefore, common features, functions, and elements may not be redundantly described here.

Process **400** may begin by an optical splitter such as the optical splitter **104** optically diverting at least one portion of an input light signal such as the input light signal **202** into at least one diverted light signal such as the diverted light signal **206** (task **402**).

Process **400** may continue by an optical amplifier such as the optical amplifier **208** amplifying the diverted light signal **206** to provide at least one amplified light signal such as the amplified light signal **210** (task **404**).

Process **400** may continue by a static phase shifter such as the static phase shifter **212** statically phase shifting the amplified light signal to provide at least one phase-shifted light signal such as the phase-shifted light signal **214** (task **406**).

Process **400** may continue by an optical combiner such as the optical combiner **110** combining the input light signal **202** with the phase-shifted light signal **214** to provide a combined phase-shifted light signal such as the combined phase-shifted light signal **216** (task **408**).

Process **400** may continue by guiding the diverted light signal **206** along at least one predetermined path using at least one waveguide such as the waveguide **218** (task **410**).

Process **400** may continue by diverting the at least one portion of the input light signal **202** from one waveguide such as the first waveguide **328** to another waveguide such as the second waveguide **330** (task **412**).

Process **400** may continue by amplifying the diverted light signal **206** via a light source such as the light source **102** (task **414**).

Process **400** may continue by the optical amplifier **208** amplifying the diverted light signal **206** via an electrical source (task **416**).

Process **400** may continue by controlling a phase shift of the combined phase-shifted light signal **216** by the optical amplifier **208** setting an amplitude of the amplified light signal **210** (task **418**).

Process **400** may continue by controlling a phase shift of the combined phase-shifted light signal **216** by the static phase shifter **212** setting a static phase shift of the phase-shifted light signal **214** (task **420**).

FIG. **5** is an illustration of an exemplary flowchart showing a process **500** for providing a phase modulator according to an embodiment of the disclosure. The various tasks performed in connection with process **500** may be performed mechanically, by software, hardware, firmware, a computer-readable medium having computer executable instructions for performing the processes, or any combination thereof. For illustrative purposes, the following description of the process **500** may refer to elements mentioned above in connection with FIGS. **1**-**3**.

It should be appreciated that the process **500** may include any number of additional or alternative tasks, the tasks shown in FIG. **5** need not be performed in the illustrated order, and the process **500** may be incorporated into a more comprehensive procedure or process having additional functionality not described in detail herein. In practical embodiments, portions of the process **500** may be performed by different elements of the system **100** through **300** such as: the light source **102**, the optical splitter **104**, the optical amplifier **106/208/310/318**, the static phase shifter **108/212/314/322**, the optical combiner **110**, etc. Process **500** may have functions, material, and structures that are similar to the embodiments shown in FIGS. **1-3**. Therefore, common features, functions, and elements may not be redundantly described here.

Process **500** may begin by providing an optical splitter such as the optical splitter **104** operable to divert at least one portion of an input light signal such as the input light signal **202** into at least one diverted light signal such as the diverted light signal **206** (task **502**).

Process **500** may continue by providing at least one optical amplifier such as the optical amplifier **208** operable to amplify the diverted light signal **206** to provide at least one amplified light signal such as the amplified light signal **210** (task **504**).

Process **500** may continue by providing at least one static phase shifter such as the static phase shifter **212** operable to statically phase shift the amplified light signal **210** to provide at least one phase-shifted light signal such as the phase-shifted light signal **214** (task **506**).

Process **500** may continue by providing an optical combiner such as the optical combiner **110** operable to combine the input light signal **202** with the phase-shifted light signal **214** to provide a combined phase-shifted light signal such as the combined phase-shifted light signal **216** (task **508**).

Process **500** may continue by providing at least one waveguide such as the waveguide **218** operable to guide the at least one diverted light signal along at least one predetermined path (task **510**).

In this manner, embodiments of disclosure provide an optical phase modulator that solves non-optimal processes associated with current optical phase modulators are solved. These non-optimal processes may comprise, for example but without limitation, an energy inefficient and slow process of dynamically changing the path length of light, a limited ability to dynamically change the refractive index in some materials, or other non-optimal process.

In this document, the terms "computer program product", "computer-readable medium", "computer readable storage medium", and the like may be used generally to refer to media such as, for example, memory, storage devices, or storage unit. These and other forms of computer-readable media may be involved in storing one or more instructions for use by a processor module to cause the processor module to perform specified operations. Such instructions, generally referred to as "computer program code" or "program code" (which may be grouped in the form of computer programs or other groupings), when executed, enable optical phase modulation methods of the system **100**.

The above description refers to elements or nodes or features being "connected" or "coupled" together. As used herein, unless expressly stated otherwise, "connected" means that one element/node/feature is directly joined to (or directly communicates with) another element/node/feature, and not necessarily mechanically. Likewise, unless expressly stated otherwise, "coupled" means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically. Thus, although FIGS. **1-3** depict example arrangements of elements, additional intervening elements, devices, features, or components may be present in an embodiment of the disclosure.

Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term "including" should be read as meaning "including, without limitation" or the like; the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; and adjectives such as "conventional," "traditional," "normal," "standard," "known" and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future.

Likewise, a group of items linked with the conjunction "and" should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as "and/or" unless expressly stated otherwise. Similarly, a group of items linked with the conjunction "or" should not be read as requiring mutual exclusivity among that group, but rather should also be read as "and/or" unless expressly stated otherwise. Furthermore, although items, elements or components of the disclosure may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated. The presence of broadening words and phrases such as "one or more," "at least," "but not limited to" or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent.

As used herein, unless expressly stated otherwise, "operable" means able to be used, fit or ready for use or service, usable for a specific purpose, and capable of performing a recited or desired function described herein. In relation to systems and devices, the term "operable" means the system and/or the device is fully functional and calibrated, comprises elements for, and meets applicable operability requirements to perform a recited function when activated. In relation to systems and circuits, the term "operable" means the system and/or the circuit is fully functional and calibrated, comprises logic for, and meets applicable operability requirements to perform a recited function when activated.

The invention claimed is:

1. An optical phase modulator comprising:

an optical splitter operable to divert at least one portion of an input light signal into at least one diverted light signal;

at least one optical amplifier operable to amplify the at least one diverted light signal to provide at least one amplified light signal;

at least one static phase shifter operable to statically phase shift with a constant shift in phase the at least one amplified light signal to provide at least one phase-shifted diverted light signal; and

an optical combiner operable to combine the input light signal with the at least one phase-shifted diverted light signal to provide a phase-shifted combined light signal at an output of the optical combiner, wherein a magnitude and power of the output is equal to a magnitude and power of the phase-shifted combined light signal at the input light signal, wherein the input light signal traverses a path from the optical splitter to the optical combiner that is unamplified and not phase shifted.

2. The optical phase modulator of claim **1**, wherein the at least one optical amplifier comprises at least one of: a light source, and an electrical source.

3. The optical phase modulator of claim **1**, wherein a maximum total power of the at least one optical amplifier is equal to an input signal power of the input light signal and proportional to an efficiency of the at least one optical amplifier.

4. The optical phase modulator of claim **1**, further comprising at least one waveguide operable to guide the at least one diverted light signal along at least one predetermined path.

5. The optical phase modulator of claim **4**, wherein:

the at least one waveguide comprises at least two waveguides; and

the optical splitter is further operable to divert the at least one portion of the input light signal from one of the at least two waveguides to another.

6. The optical phase modulator of claim **5**, wherein the at least two waveguides comprise a first waveguide comprising a first waveguide length, and a second waveguide comprising a second waveguide length that is 2.1 radians greater or less than the first waveguide length.

7. The optical phase modulator of claim **1**, further comprising a processor operable to modulate a phase shift of the at least one phase-shifted diverted light signal by controlling an amplitude of the at least one amplified light signal, wherein the magnitude and the power of the phase-shifted combined light signal at the output is equal to the magnitude and the power of the input light signal.

8. The optical phase modulator of claim **1**, wherein the at least one static phase shifter is further operable to be set to a specified static phase shift.

9. A method for dynamically phase shifting a light signal, the method comprising:

optically diverting at least one portion of an input light signal into at least one diverted light signal through an optical splitter;

amplifying the at least one diverted light signal to provide at least one amplified light signal;

statically phase shifting with a constant shift in phase the at least one amplified light signal to provide at least one phase-shifted light signal; and

combining the input light signal with the at least one phase-shifted light signal to provide a combined phase-shifted light signal at an output of an optical combiner, wherein a magnitude and power of the combined phase-shifted light signal at the output of the optical combiner is equal to a magnitude and power of the input light signal, wherein the input light signal traverses a path from the optical splitter to the optical combiner that is unamplified and not phase shifted.

10. The method of claim **9**, further comprising amplifying the at least one diverted light signal via a light source or an electrical source.

11. The method of claim **9**, further comprising guiding the at least one diverted light signal along at least one predetermined path using at least one waveguide.

12. The method of claim **11**, further comprising diverting the at least one portion of the input light signal from one waveguide to another waveguide.

13. The method of claim **9**, further comprising modulating a phase shift of the combined phase-shifted light signal by controlling an amplitude of the at least one amplified light signal, wherein the magnitude and the power of the combined phase-shifted light signal at the output of the optical combiner is equal to the magnitude and the power of the input light signal.

14. The method of claim **9**, further comprising controlling a phase shift of the combined phase-shifted light signal by setting a static phase shift of the at least one phase-shifted light signal.

15. A method for providing an optical phase modulator, the method comprising:

providing an optical splitter operable to divert at least one portion of an input light signal into at least one diverted light signal;

providing at least one optical amplifier operable to amplify the at least one diverted light signal to provide at least one amplified light signal;

providing at least one static phase shifter operable to statically phase shift with a constant shift in phase the at least one amplified light signal to provide at least one phase-shifted light signal; and

providing an optical combiner operable to combine the input light signal with the at least one phase-shifted light signal to provide a combined phase-shifted light signal at an output of the optical combiner, wherein a magnitude and power of the combined phase-shifted light signal at the output of the optical combiner is equal to a magnitude and power of the input light signal, wherein the input light signal traverses a path from the optical splitter to the optical combiner that is unamplified and not phase shifted.

16. The method of claim **15**, wherein providing at least one optical amplifier comprises providing at least one of: a light source, and an electrical source.

17. The method of claim **15**, further comprising providing at least one waveguide operable to guide the at least one diverted light signal along at least one predetermined path.

18. The method of claim **17**, wherein providing at least one waveguide comprises providing at least two waveguides, the optical splitter further operable to divert the at least one portion of the input light signal from one of the at least two waveguides to another.

19. The method of claim **15**, further comprising providing a processor operable to modulate a phase shift of the at least one phase-shifted light signal by controlling an amplitude of the at least one amplified light signal, wherein the magnitude and the power of the combined phase-shifted light signal at the output of the optical combiner is equal to the magnitude and the power of the input light signal.

20. The method of claim **15**, wherein providing the at least one static phase shifter comprises providing the at least one static phase shifter further operable to be set to a specified static phase shift.

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